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ASSESSMENT OF PUBLIC BOREHOLES WATER QUALITY IN MAIDUGURI METROPOLIS

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Abstract

In this study, the quality analysis of borehole water from various locations in Maiduguri metropolitan was investigated to determine the condition of groundwater in the Council following recent influx of people with resultant increase in human activities. Water samples were collected from boreholes at five different locations *viz* Bolori, Gwange, Shehuri, Kyarimi park and Bulunkutu. The locations were selected based on operational offices as stipulated and designed by Borno State Water Board (BSWB) within the city. The pH, EC, and TDS of the water samples were analysed using combined pH/EC/TDS combo (Hanna instrument) Model HI 98130 while bacteriological analysis was conducted according to American Public Health Association. The results show that the pH of ground water in all the five locations ranged between 6.56 and 7.12 which was within World Health Organization (WHO) standard for drinkable water. Electrical Conductivity (EC) of the samples ranged from 128±0.42 to 168±0.47 (µs/cm) and was within the WHO standard for drinkable water of 1200µs/cm. Also, turbidity ranged from 1.13 to 1.35 NTU while total dissolved solid (TDS) was ranged from 85 to 121 mg/L and were all within the stipulated limits. In addition, the alkalinity values of the samples ranged from 89 mg/L for Gwange area which showed that, it was WHO complaint while 150±65.6 mg/L was recorded in Bulunkutu area which was above the prescribed limit of 150 mg/L. Furthermore, the concentration of Mg ranged from (1.01 to 7.53 mg/L), Ca (7.53 to 16.05), while Iron (Fe) was detected only in one borehole in Shehuri (0.25 mg/L) whereas Chloride was ranged from (13.4 to 25.5 mg/L). Interestingly, they were found to be within the stipulated WHO standards. The Biological quality of water from Gwange (S_3) and Bolori (S_1) showed that the concentration of *E-coli* was the same, 13×10^3cfu/100ml while that of Bulunkutu (S3) was 3×10^3 cfu/100ml respectively. These values are above the maximum permissible limit 0 cfu/100ml of *E-coli* for drinking water. Therefore, borehole water obtained from some locations in Maiduguri might require some level of treatments before use for domestic purposes.

Keywords: Water quality, Maiduguri, Borehole, domestic use, pollution

1. Introduction

Water is a universal solvent which dissolves many organic and inorganic substances. Absolutely pure water almost never exists in nature. Pure water contains only two molecules of hydrogen and a molecule of oxygen. However, rainwater might be considered as pure water. Conversely, as rain falls, some atmospheric gases dissolve in them and cause the water to be contaminated. Water acquires more impurities as it dissolves minerals and salts by flowing over or through their deposits after falling on the ground. Similarly, it has been reported that the type and extent of chemical contaminants in groundwater depends on the geochemistry of the soil through which the water passes to the aquifers (Abdulaziz, 2003). Contaminated water affects drinking water demand across the various sectors of the society. Good water quality could increase the rate of demand while on the other hand poor water quality could result in decrease in water demand rate (Shannon et al., 2008) In Maiduguri metropolitan, however, ground water is one of the main source of water supply used by most households (Bakari, 2014). Water quality concern is an important component for measuring access to improved water sources. Presently, there has been incessant influx of people into the city which has impacted on water demand. It is noteworthy that human activities could affect the physio-chemical and bacteriological quality of water.

Maiduguri is one of the major trade Centre in the Northeastern Nigeria. Traders from neighbouring countries such as Republic of Cameroon, Chad, and Niger (Kolo *et al.*, 2009) visit Maiduguri frequently for different business purposes. The city has industrial sectors that include: plastics, leather, metals, confectionaries and beverages. Access to clean water, sanitation and hygiene are significant elements for poverty alleviation and improved health (WHO, 2015). Conversely, chemical contaminants occur in drinking water throughout the world which has posed greater threat to human health (Ezeribe *et al.*, 2012). In the same vein, the quality of water as well as quantity of water is affected by increasing human activities and any pollution, either physical or chemical causes changes to the quality of the receiving water body (Aremu *et al.*, 2011).

Depending on individual household's perception on taste, odor and appearance (Doria, 2010), people have different opinions about the aesthetic values of water quality. According to WHO, (2006) consumer perceptions and aesthetic criteria need to be considered in assessing drinking water supplies even though they may not have any adverse effect on human health.

The aim of this study was to assess water quality from public boreholes in Maiduguri metropolitan area and to observe whether it is WHO compliant. Additionally, public perception of water quality (consumer satisfaction) would be evaluated.

2. Materials and Methods

2.1 Study area

Maiduguri is located between latitudes 11 42N and 12 00 N and longitudes 12.54 and 13 14 E and 340 m elevation above sea level (Haruna, 2009). Figure 1 shows the map of Maiduguri the capital city of Borno State which covers an area of 69,436 km^2 and has about 1,197,497 inhabitants with mean annual growth rate of 2.8% (NPC, 2007). The area has mean annual rainfall of 800mm and a low relative humidity ranging from 42% to 49%. Jere Local Government Area (LGA) bounds the city on the North and West. On the south and southwest is Konduga LGA, and on the Eastern part of the city is bound by Mafa LGA. The City has temperature ranging between 30^{o}C and 40^{o}C. The hottest months are March and April, while November to January are the coldest and driest periods of the Harmattan.

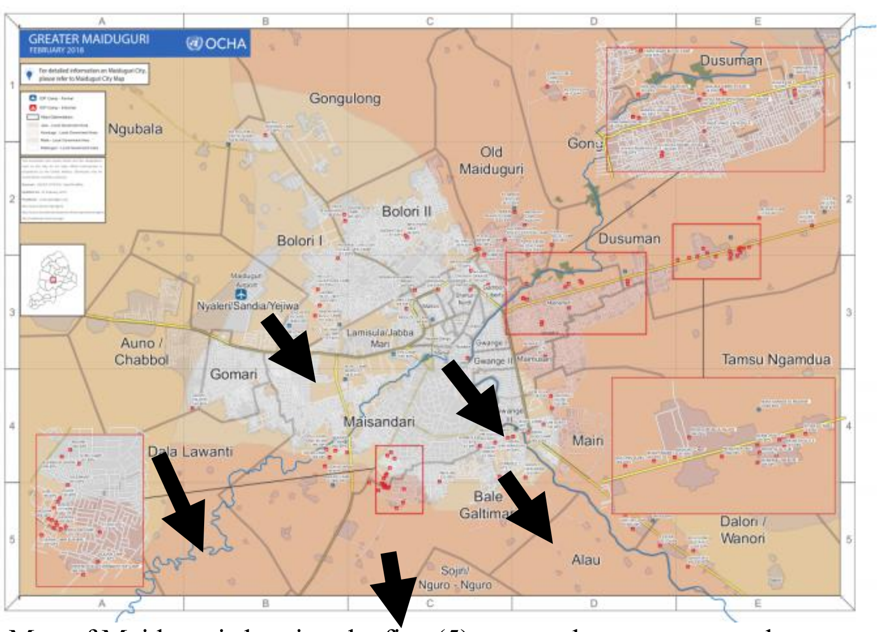

Figure 1: Map of Maiduguri showing the five (5) zones where water samples were collected. Source: https://reliefweb.int/sites/reliefweb.int/files/resources/_maiduguri_map_surroundings.pdf

2.1 Data collection method

Maiduguri-Jere town was divided into five (5) zones namely, Bolori, Shehuri, Gwange, Kyarimi park and Bulunkutu areas respectively as designated by Borno State Water Board (BSWB). Data were collected through a household surveys using structured questionnaires regarding time taken to fetch water from source, occurrence of any health-related problems upon consumption, household drinking water supply and bacteriological quality of water from the source of supply. Also, water samples were collected from public and private boreholes (including boreholes where water vendor buy and sale to the general public). The water samples were collected directly from the boreholes using 500ml sterilized bottles. Before sampling for laboratory analysis, sample bottles were cleaned by soaking them in water with detergent for 2-3 hours, followed by washing them with clean, coarse sand and rinsing several times with hot water until they were free of detergent and sand. Three water samples were collected from three boreholes in each area labelled as (S1, S2, and S3).

Each sample bottle was labeled based on the initial alphabet of the name of the area from which the water sample was collected. These include: Kyrimi park area (K), Gwange area (G), Shehuri area (S), Bolori area and (B) Bulumkutu area (Bu). The borehole taps were sterilized with detergent before sample collection. The polyethene bottles were filled with water up to half (about 300ml) leaving space to ensure adequate shaking before analysis (Isa, 2013). The water samples were taken to the laboratory within 2 h of collection in a dark (light proof) polyethene bag in order to prevent possible alteration of chemical and biological parameters by light.

2.2 Sample Analyses

The samples were analysed for biological, physical (Organoleptic) and Chemical parameter immediately after reaching the Maiduguri water treatment plant laboratory. The bacteriological parameters include: total coliforms and faecal coliforms (particularly, faecal E-coli) and they were analysed using filter membrane technique by incubating the membrane on a growth promoting medium for 24 h at 37^{o}C and 44.5^{o}C, respectively, and counting to estimate the resultant colonies per 100ml of samples collected from borehole/tap water (Bakari, 2014; Mtewa et al., 2018). Some physicochemical parameters such as TDS pH and EC were determined using digital pH meter (model HANNA HI 98130, combo) following Mtewa et al., (2018) while the other parameter such as: colour, alkalinity, turbidity, total hardness, copper, calcium, manganese, magnesium, iron, phosphate, chloride, sulphate, nitrate, fluorite and nitrite were tested according (APHA, 1998). The temperatures of the samples were determined using digital thermometer. The laboratory tests were conducted at Water Treatment Plant Maiduguri. All experiments were conducted in triplicate.

3. Results and Discussion

3.1 Physicochemical Properties of the water Samples

Table 1 presents the physicochemical properties of all the water samples collected from the five zones. The results show that the temperature of all the samples are largely within the WHO standard for drinking water. Temperature could affect suitability of drinking water as it impacts the survival of microbes in aquatic environment. Similarly, temperature could affect the treatability of water because most coagulants works well in warm than in cold water temperature (Jones and Bridgeman, 2016). Additionally, the turbidity of the samples ranged between 1.13±0.29 and 1.35±0.55 NTU for all the areas (Gwange, Kyarimi park, Bulunkutu and Shehuri area) respectively. WHO has stipulated a maximum limit for turbidity at 5 NTU for drinking water. Turbidity defines the esthetic of drinking water source and its presence at higher concentration above the maximum permissible limit could harbor pathogens in water against disinfectant chemicals. High turbidity in water is associated with particulates, bacteria and planktons (Shittu *et al.*, 2008). The pH of all the samples ranged from

6.56±0.10 and 7.12±0.34 which falls within the recommended level by WHO standards for drinking water of 6.5/6.5 to 8.5 respectively. Shehuri area has the highest pH of 7.12±0.34 and Gwange has the lowest pH of 6.56±0.10, though still within the limit. It has been observed that a 1% change in water pH can significantly affect water quality by 1°C change in temperature in chemical reaction (Afiukwa and Eboatu, 2013). However, dissolution and absorption of toxic substances increases at low temperature; especially, in soils with higher carbonate and lower silicate concentration. Low pH increases acidity and this supports its impact on geological materials, which results in leaching of toxic from trace metals into watercourse. Consequently, it makes the water harmful for human consumption (Kolo *et al.*, 2009). Incidentally, continued consumption of acidic or alkaline water might cause gastrointestinal corrosion resulting in ulcers (WHO, 2008).

The total dissolved solids (TDS) of water obtained from boreholes in Shehuri area (83±0.10 mg/l), Kyarimi Park (76 ±1.21 mg/l) and S_1 in Gwange area (55±0.17mg/l) (Table 1). The results are lower than the recommended value of 1000mg/l as stipulated by WHO for drinking water. The results presented in this work are in agreement with that reported by Isa *et al.,* (2012). Isa *et al.,* (2012) has reported a range of value from (94 to 574 mg/l), which could mean that the TDS changes from time to time depending on weather conditions. On the other hand, the conductivity of the samples ranged from (128±0.42 to 168±0.47 µs/cm), and this is within the WHO standard for drinking water of (1200 µs/cm). In addition, sample from Shehuri area has conductivity as high as (168±0.47 µs/cm) and in Bolori area the lowest of 128±0.42 µs/cm. The conductivity of water is an expression of its ability to conduct an electric current, thus, it is related to the ionic content of the sample, which is also a function of the dissolved (ionisable) solids concentration. Nonetheless, conductivity is a property of little interest to a water analyst but it is an invaluable indicator of the range into which hardness and alkalinity values are likely to fall, and also of the order of the dissolved solids content of the water. It is noteworthy that there is an interrelationship between conductivity and temperature, the former increasing with temperature at a rate of some 2 per cent per degree (°C) rise. The alkalinity values of the samples range from (89±0.38 mg/l) for Gwange area and (144±0.51 mg/l) for Kyarimi Park: these values are within the maximum permissible level of WHO (150 mg/l).

Table 1: Physicochemical Properties of Water Samples from selected boreholes in Maiduguri.

		Locations					**Guidelines**
S/N	Parameter	Kyarimi	Gwange	Shehuri Area	Bulumkutu	Bolori Area	WHO
1	Temperature (°C)	27.50±0.58	28.9±0.26	26.4±072	28.8±0.74	28.50±2.19	30
2	Colour	2.00±0.00	1.33±0.58	2.00±1.41	2.50±0.71	2.00±0.00	5
3	Turbidity NTU	1.35±0.55	1.13±0.29	1.25±0.30	1.21±0.29	1.16±0.32	5
4	TDS mg/l	103.00±0.23	85±1.24	121±0.26	111±8.50	86.00±0.18	1000
5	pH	6.97±0.24	6.56±0.10	7.12±0.34	7.05±0.43	6.80±0.21	6.5-8.5
6	Conductivity (µs/cm)	153.00±2.34	140±0.43	168±0.47	161±1.31	128.00±0.42	1200
7	Alkalinity (mg/l)	144.00±0.51	89±0.38	138±8.70	150±1.65	100±0.24	150
8	Total Hardness (mg/l)	76.00±21.90	55±17.10	83±10.40	67±21.00	64.00±22.90	500
9	Calcium (mg/l)	16.05±13.30	7.37±2.62	10.7±0.49	14.04±10.54	7.53±2.75	75
10	Magnesium (mg/l)	2.10±0.71	1.19±0.30	1.01±0.06	1.71±0.62	7.53±2.75	50
11	Copper (mg/l)	0.10±0.00	0.04±0.01	0.07±0.00	0.17±0.07	ND	2
12	Iron (mg/l)	ND	ND	0.025±0.07	ND	ND	0.3
13	Phosphate (mg/l)	0.77±0.65	0.53±0.42	0.66±0.11	0.66±0.46	0.22±0.07	6.5
14	Chloride (mg/l)	21.50±6.22	16.0±1.70	13.4±2.89	25.5±0.85	18.00±2.00	250
15	Sulphate mg/l	6.98±1.14	7.08±2.88	4.95±0.95	5.37±1.31	6.54±1.28	400
16	Flouride mg/l	0.40±0.23	0.17±0.04	0.16±0.05	0.48±0.10	0.22±0.04	1.5
17	Nitrite mg/l	ND	ND	ND	0.05±0.01	0.07±0.01	0.2
18	Nitrate mg/l	2.03±1.03	1.66±0.98	1.46±0.48	2.49±2.18	19.00±0.13	5

All values are mean±Standard deviation of samples from each area. ND=not detected.

Furthermore, the total hardness results of all the samples indicated that they are within the WHO specification limits for drinking water, though could cause hardness of water. Therefore, this explains further presence of carbonates/bicarbonates, which may cause poor lather formation and scales on boilers (Durrance, 1986). The use of hard water for domestic purposes may lead to soap wastages during washing, it also brings eye and skin discomfort (Kolo *et al.*, 2009). However, hard water has both economical and medical implications. Boiling can remove temporary hardness. But, hardness, which occurs naturally in water, is an aggregate parameter that is the sum of aqueous divalent cations. For example, calcium and magnesium are the major divalent cations in natural fresh waters, and hence the major ions in hardness. The calcium ion (Ca^{2+}) and Magnesium ion (Mg^{2+}) can cause water hardness, which may result in depositing limestone type materials in underground soil layers. Boreholes in Kyarimi Park area has the highest mean of calcium content (16.05±13.3 mg/l) and Gwange area has the lowest calcium content (7.37±2.62 mg/l). Calcium content of the samples was within allowable limit of calcium in drinking water when compared to WHO and maximum permissible content of (75mg/l and 65mg/l) respectively. The magnesium content for all the samples is within the standard limits. The presence of high calcium and magnesium level shows water hardness within sources of water. Hardness of water causes greasy rings on the bathtubs, film on dishes or hair after washing and poor laundry results. Copper content ranged from (0.17±0.00 to 0.04±0.01 mg/l), with the water sample from Bulumkutu area having the highest copper content (0.17±0.00 mg/l) and there no copper detected (ND) from Bolori area samples. Gwange area also shows the lowest copper content (0.04±0.01 mg/l). Manganese is a hazardous chemical because it causes neurological disorder in human and causes troublesome stains and deposits on light coloured clothes and plumbing fixtures; also, when it is in excess amount can cause dark colouration and unpleasant taste in some food and beverages (NSDWQ, 2007). The WHO maximum allowable limit of Manganese is (0.2mg/l) and anything beyond this value is dangerous to health. From Table 1 it can be observed that manganese was not detected for all the water samples collected from all the selected areas in Maiduguri. Thus, all the samples were considered free from manganese.

The iron content of all the water samples used in this study is within the WHO standards of (0.3 mg/l) (WHO, 2008). Despite iron in water is not of health concern, high concentrations of iron affect the quality of water, leading to bad taste and colouration of cooking utensils and food (Schafer *et al.*, 2009). Analyses of the result also showed that phosphate content for the entire samples are also within the WHO standard. The highest concentration of (0.77±0.65 mg/l) obtained from Kyarimi Park borehole and the lowest value (0.22±0.07 mg/l) obtained from Bolori area water samples.

Chlorides in natural waters such as well water result from the leaching of chloride-containing rocks and soils as it comes in contact with water. The samples are within the limits set by WHO (200 and 250 mg/l). Chlorides are the most stable components in water and its concentration is largely unaffected by most natural physio-chemical and biochemical processes. Hence, the value of its concentration in water is a useful measure in water sample. Large concentrations increase the corrosiveness of water and, in combination with sodium, give water a salty taste (NSDWQ, 2007). Sulphate (SO_4) content exceeds 100 mg/l tends to give water a bitter taste and have a laxative effect on people who are not adapted to the water. In the water sample collected from all the boreholes/taps have low sulphate content ranging from 4.95±0.95 mg/l for sample from Shehuri area to 7.08±2.88 mg/l for boreholes from Gwange area. All water sources in the study area are of low sulphate content when compared to WHO permissive level. High sulphate concentration can cause intestinal irritation (Ibrahim and Ajibade, 2012). Fluoride content for all the sampled boreholes/taps water also ranged (from 0.16±0.05 to 0.48±0.10 mg/l) within the WHO standard limit. The sample from Bulumkutu

area has the highest value of 0.48±0.10 mg/l and Shehuri area has the lowest value of 0.16±0.05 mg/l.

Nitrite was found to be 0.05±0.007 mg/l for samples from Bulumkutu area and 0.07±0.01 mg/l for Bolori area. However, nitrite was not detected in samples from the other three areas. Nitrate (NO3-) in excess of 45mg/l is of significance health implication especially to pregnant women and infants under six months. Nonetheless, all boreholes/taps water sampled nitrate content fall within the allowable value stipulated by WHO.

A Nitrate concentration of more than 50 mg/l impacts bitter taste to water and may cause physiological distress, and in infant can cause methemoglobinemia. Nitrate fouls the water system and epidemiological studies predicted association between exposures to nitrate and gastric cancer, because of the reaction of nitrate with amine level diet forming acidic carcinogenic into sameness (WHO, 2007). All the boreholes/taps in Maiduguri metropolis are within the WHO standard for portable water quality concerning Nitrate.

3.2 Bacteriological water quality assessment

This study shows that all water samples collected from these boreholes tested positive for total coliforms with values ranging from $7x10^3$cfu/100ml (Bolori S_3 and Kyarimi Park S_3) to $82x10^3$cfu/100ml (Bolori S_1). Samples from Bulumkutu S_3 and Gwange S_3 have concentration of $10x10^3$ cfu/100ml and $68x10^3$cfu/100ml as shown in (Figure 2). The differential *Escherichia coli* (*E-coli*) count for all the samples were found to be zero colonies forming units per 100ml except for samples from Bolori S_1, Bulumkutu S_3 and Gwange S_3 with concentration of $13x10^3$cfu/100ml, $3x10^3$cfu/100 ml and $13x10^3$cfu/100 ml respectively (Figure 2). The presence of *E-coli* content in water at whatever concentration is not permissible in any domestic consumable water (Cheebrough, 2003). Water samples with moderate content of *E-coli* range between 0-10 cfu/100ml (Cheebrough, 2003). Also, the standard organization of Nigeria (SON, 2007) set a maximum permissible limit of Total coliform as 10cfu/100ml. Boreholes water from Bolori S_1, Bulumkutu S_3, and Gwange S_3 has higher values of *E-coli* which are beyond WHO permissible limit of 0 cfu/100ml. The *faecal coliform* for all the samples were also within the permissible limit except for Bolori S_1 (>180 MPN), Bulumkutu S_3 (21 MPN), and Gwange S_3 (>180 MPN), which exceed the maximum limit. Additionally, the presence of *faecal coliforms* suggests that the water contain microbiological agents that may pose health problems such as gastrointestinal diseases (Svagzidiene and Page, 2010).

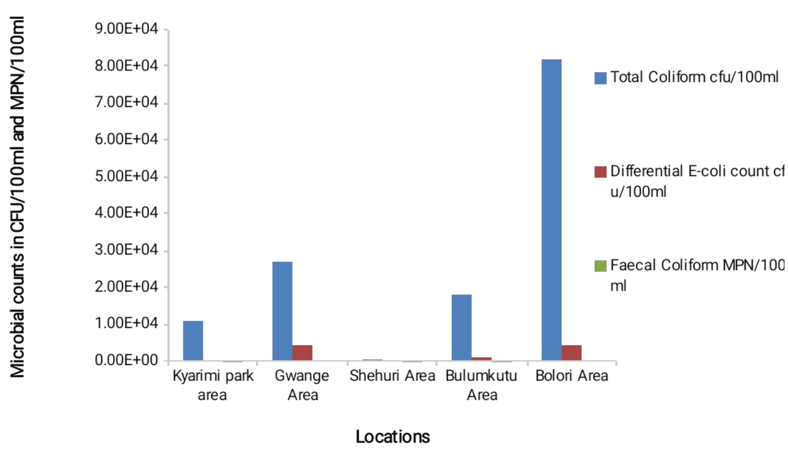

Figure 2: Microbiological Characteristics of some borehole water samples in Maiduguri.

The total coliform and *E-coli* bacterial contamination in Gwange S_3 and Bulumkutu S_3 are attributed to the environmental condition of the area; poorly maintained sewage system and poor handling by the borehole operators. Poor disposal of refuse from residential houses surrounded the water points could be another attribute to the rate of contamination. Also, the borehole from Gwange (S_1) is located close to a river, where a lot of organic refuse and feaces are being discharged. Borehole from Bolori S_1 has heavy bacterial load as indicated by the concentration of total coliform as high as $82x10^3$cfu and differential *E-coli* count of $13x10^3$cfu which is in agreement with the finding of Jimme et.al, (2016). The bacteria contamination in borehole in Bolori S_1 could be attributed to biofilm formation in pipes and underground reservoirs.

3.3 Respondents Perceptions of Water Quality

In this study, factors such as taste, odor, and color were found to be very important in households' perceptions of water quality. The acceptability of drinking water depends on the perception of consumers and the resultant complaints due to tastes, odors, color or any other form of particle present which may affect public health. Besides coverage, the sufficiency and quality of the improved sources must also be considered in the discussion on access. However, those households who are satisfied with the current main source of water supply, their willingness to pay are significantly enhanced. Conversely, households who are not satisfied, their willingness to pay decreased accordingly. It was further observed that households may not be interested to pay if they are not really satisfied with water supply service. It is clear that consumers satisfaction and perceived quality of the source were factors determining willingness to pay for improved services. Figure 3 (A) shows that it was possible to draw priorities of the people to achieve their desire among the two parameters such as water quality and quantity based on their willingness to pay. Therefore, taking the normal situation, and assuming the water supply source delivery is safe and enough quantity of water is supplied households were more willing to accept to pay for quantity or availability of water than quality of water. The study also revealed in Figure 3 (B) that 37% of the respondents' trek more than 50-99m to fetch water on daily and 14% of the respondents trek a distance of about 100-199m to water source. This shows that water fetching in this area is tasking and can result in frequent illness of women and the young ones, who are in most cases, responsible for fetching water. A huge amount of time and energy is exhausted in fetching water in the study area.

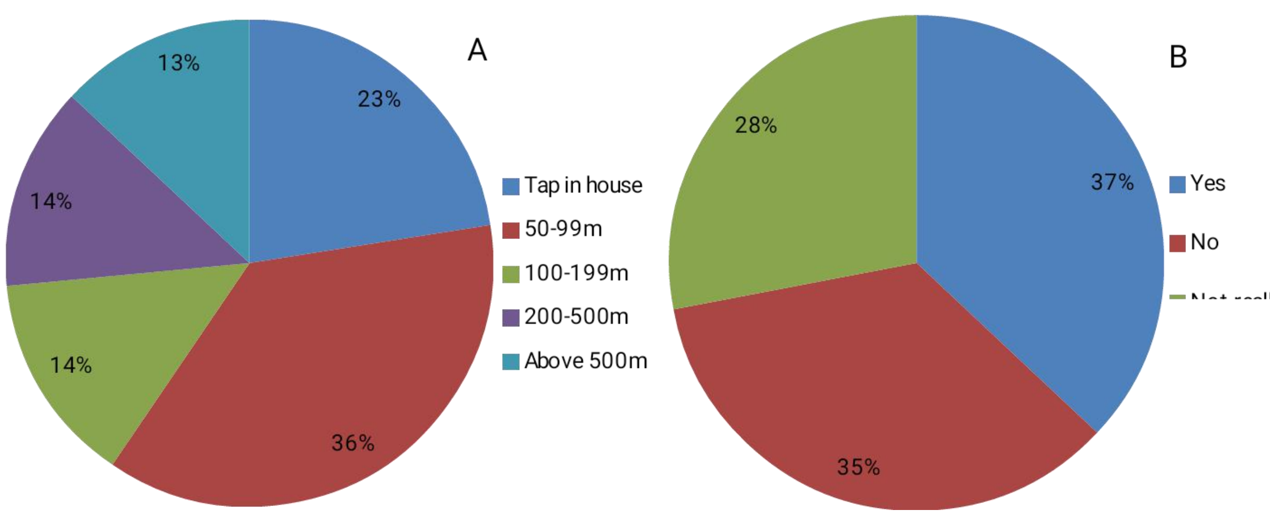

Figure 3: Shows level of consumer satisfaction with water supply (A) and distance from their main source of water supply (B).

4. Conclusion

Information on water quality should be considered as a reflection of quality of life. However, people may be aware of the dangers associated with the consumption of poor water quality but lack of boreholes and distance to water sources could be a driving factor that makes consumers to collect water from alternative sources even of low quality. The results indicated that most boreholes in Maiduguri are not safe for drinking as there are reasonable presence of *E-coli* in the water samples tested which might have been polluted. Effort should be made to ensure that drinking water is periodically checked to ascertain its quality. Public perception of a particular source should be considered when planning a water supply project in order to add value to the overall aim of the water supply scheme within the city.

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